QuickLakeH2014
An International Workshop on Lakes and Human Interactions
15-19 September 2014, Ankara and Konya, Turkey
Guidebook of the QuickLakeH2014
An International Workshop on Lakes and Human Interactions
15-19 September 2014, Ankara and Konya, Turkey

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Field Excursion to Konya region

Lake Tuz, Lake Beyşehir, Çatalhöyük and Meke Maar Lake and releavent features

Compiled by
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Konya - Turkey
PREFACE

Lakes are relatively simple phenomena, however they may be developed by various processes in different environments, e.g. rift and strike slip related tectonic lakes are bounded by faults that cause parts of the land surface to subside relative to the surrounding area (Such as Lakes Beyşehir and Tuz). Depressions lake related to broad subsidence of the crust (sag basins) tend to be larger and shallower; A depression created by wind on the land surface may later be filled with water. Glaciers can also scour more deeply into a valley. Lakes may be formed by landslides that block the path of a stream in a valley and large volumes of volcanic ash or lava that can create topography on the land surface and result in the formation of a lake (Lake Van in eastern Turkey). Volcanic activity can also create large lakes by caldera collapse (Meke lake) and explosive eruptions that remove large quantities of material from the centre of a volcanic edifice, leaving a remnant rim within which a crater lake can form.

The fauna, flora and chemistry of lake waters varies from lake to lake. The majority of large modern lakes are freshwater (such as Lake Beyşehir) occurring at latitudes ranging from the Equator to the polar regions. There is no direct relation between the surface area and water depth of lake. For example, Lake Tuz is the second largest lake in Turkey but its depth is about 1 meter.

Most of the settlements starting from ancient time mainly took place around water-rich areas; along the rivers and lakes. In order to carry on the life, we need water for ourselves, animals and farming. Lakes may be utilized for different purposes such as for supplying drinking and irrigation water, fishing, recreation and transportation.

The lakes in Anatolia became recede about 10.000 years ago following the warming in the climate. Due to dropping of the water level, new large areas appropriate for agriculture emerged. People who wanted to utilize these lands settled around the lakes. Such settlements were established at lakes region in Central Anatolia during neolithic period. Most important settlements representing this period are Çatalhöyük (Paleo-Konya Lake), Suberde ve Erbaba (Lake Suğla and Beyşehir) settlements.

For Turkey, the interactions between human and nature, as discussed in current literature, are mainly limited to the earthquake and its destructive effects. One of the purposes of this workshop is to discuss the roles of lakes on the anthropologic developments and to introduce (exhibit) the view of earth scientists about far and near past events. For example, a lot of settlements very close to the lake shores, dated as Rome, Byzantium, Seljuc and Ottoman period, were abandoned because of changes in the lake level and, the rising water level in the Caspian Sea, Urmiya Lake and Van Lake in 1978-1995 caused enormous damages, lost of farming land and migration of thousands of families. The damages and the reasons for rising lake level are still under investigation.

Another example for the extent of QuickLakeH workshops, a subject which was discussed in 2013 and became more popular after the results were published in Nature under the title of “Cengiz Han, the secret of being the biggest empire in history within a human life”. The fundamental data for this study were obtained from cores taken in the Holocene lake at Central Asia and pollen analysis. Studies showed that climate change resulted in the development of wetlands and grasslands during this period so that horse herd were breed easily, and that Cengiz Han took advantages of these. Briefly the interaction between nature and human need to be well understood and earth scientists may contribute a lot in this respect.

We, the organizers hope the presentations and field excursion of the QuickLakeH2014 workshop will be beneficial for participants about the interactions between lakes and human life, especially climate and natural changes. These notes aim to introduce generally two two large lakes (Lakes Tuz and Beyşehir) to be visited during the excursion.
Lake Tuz, the second largest lake in Turkey, is located in the arid central plateau of Turkey in Central Anatolia (Fig. 1), 105 km NE of Konya and 150 km SSE of Ankara. The surface area of the lake reaches to 1665 km² in spring. The altitude of the lake is 905 m. It is one of the most salty lakes of the world with salt ratio of 32.4%. This feature brings an economic value as well, of which 70% of salt used in Turkey is produced from that lake.

The primary feeding sources of the lake are groundwater and precipitation. The lake is fed by three major rivers (Fig. 2); Peçeneközü, Ulurmak and Insuyu, with mean annual discharge rates of $37 \times 10^6$, $41 \times 10^6$ and $10 \times 10^6$ m³, respectively. Several ephemeral stream and one man-made agricultural discharge canal with a mean annual discharge rate of $87 \times 10^6$ m³ also feed the lake (DSİ, 2003; Kılıç and Kılıç, 2010). Mean annual precipitation averages $353 \pm 36$ mm and the potential monthly evaporation ranges from 1175 - 1390 mm (MTA, 1982; Kılıç and Kılıç, 2010).

In or near the shore of Lake Tuz, halite is produced by the solar evaporation method in a number of saltworks, such as the Yavşan, Kaldırım and Kayacık saltpans (Fig. 2). In Lake Tuz, the overall salt production by this method is about 2,500,000 tons/year (Uyanik, 2004). The surface area of the lake reaches to 1665 km² in spring but, the water coverage of the lake changes along the year (Fig. 3).
Figure 2. Satellite image for saltpans in Lake Tuz.

Figure 3. Seasonal water coverage in the year 2007 (Gürol et al. 2008).
During summer, %95 of water in Lake Tuz dries up and leaves an average of 30-80 cm thick salt layer. This salt layer is seen as a bright white color from space via satellites observatory tools. Lake Tuz has been used as the reference for the color white from space for calibration of space shuttles remote sensing records for the entire World (http://whc.unesco.org). Because it meets most of the strict requirements for a radiometric calibration site such as being a bright natural target, free of vegetation, occupying a sufficiently large, flat and homogeneous area and having semi-arid climate, low loading of atmospheric aerosol, high surface reflectance and a high probability of clear weather. (Gürol et al 2008; www.uzay.tubitak.gov.tr).

Lake Tuz has been included on the United Nations list of “Special Environmental Protection Areas after the declaration of by the Decision of Cabinet of Ministers numbered 2000/1381 dated 14.09.2000. If Lake Tuz is ultimately included on the UNESCO World Heritage list, then for the first time a natural area, rather than a cultural one, in Turkey will have been declared part of the World Heritage. Lake Tuz Special Environmental Protection Area (SEPA) in Turkey managed by General Directorate for Protection of Natural Assets (GDPNA) is a very large protected area 7414.40 km². The area of Lake Tuz (SEPA) is over total surface areas of some European countries.

Lake Tuz is located in the Lake Tuz basin formed during the Late Cretaceous time and covers an area of about 16,000 km². This basin is currently bounded by the northwest- to southeast-trending Tuzgölü fault (Çemen et al., 1999). In this basin, an ophiolitic complex known as the Ankara Melange (nappes) constitutes the basement, which is unconformably overlain by a thick sedimentary cover accumulated between the Late Cretaceous and the Pliocene (Fig. 4; Uygun, 1981; Görür et al., 1984; Ayyildiz, 2000; Uygun et al., 1982; Tekin et al. 2007; Aydemir, 2008). A number of evaporite units of various ages (Upper Cretaceous, Paleocene, Middle Eocene, and Oligo-Miocene) are interlayered in this sedimentary cover. Holocene sediments of the Lake Tuz basin occupy a depression—Lake Tuz and surrounding mudflats—about 80 km long and 50 km wide at an average elevation of 905 m. Sediments in this depression are mainly composed of gypsum, dolomite, magnesite, huntite, and polyhalite (Irion and Müller, 1968; Irion, 1970; Ergun, 1988; Gündoğan and Helvaci, 1996; Çamur and Mutlu, 1996; Tekin et al., 2006).

Figure 4. Geological map of the Tuz Gölü Basin (MTA, 2002; for legend please see p.32).
The lake was divided into two zones with respect to a barrier, the inceburun sill, by Erol (1969): a main zone to the west of and a deep zone to the east (Fig. 2). The main zone water level averages 70 cm in spring but dries in summer or early fall; the minimum levels in September/October and maximum water levels in September/October and in March/April. The deep zone maintains its water content throughout the year and the water level reaches >1 m in spring. (Uygun and Şen, 1978; Uygun, 1981; Camur and Mutlu, 1996; Koday, 1999; Tekin et al. 2007; Kılıç and Kılıç 2010).

As suggested by Irion and Muller (1968) and Uygun and Şen (1978), these two zones exhibit different chemical and mineralogical characteristics as well. Mean ion concentrations of the Lake Tuz brine in a yearly cycle are given in Table 1 and 2 (Çamur and Mutlu, 1996).

Table 1. Mean ion concentrations (mg/l) of the Lake Tuz brine in a yearly cycle (Çamur and Mutlu 1996, Kılıç and Kılıç 2010).

<table>
<thead>
<tr>
<th>Month</th>
<th>K Na</th>
<th>Ca</th>
<th>Mg</th>
<th>SO₄</th>
<th>Cl</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>1610</td>
<td>115625</td>
<td>617</td>
<td>4445</td>
<td>9675</td>
<td>188812</td>
</tr>
<tr>
<td>Feb.</td>
<td>800</td>
<td>107500</td>
<td>870</td>
<td>2100</td>
<td>6100</td>
<td>161100</td>
</tr>
<tr>
<td>Apr.</td>
<td>800</td>
<td>106300</td>
<td>1000</td>
<td>2200</td>
<td>6600</td>
<td>173100</td>
</tr>
<tr>
<td>May</td>
<td>944</td>
<td>101990</td>
<td>925</td>
<td>2860</td>
<td>7371</td>
<td>167438</td>
</tr>
<tr>
<td>Jun.</td>
<td>1458</td>
<td>114717</td>
<td>772</td>
<td>3963</td>
<td>8838</td>
<td>185454</td>
</tr>
<tr>
<td>Jul.</td>
<td>3358</td>
<td>106667</td>
<td>429</td>
<td>10591</td>
<td>19097</td>
<td>172710</td>
</tr>
<tr>
<td>Aug.</td>
<td>6300</td>
<td>113000</td>
<td>380</td>
<td>10932</td>
<td>20809</td>
<td>184104</td>
</tr>
<tr>
<td>Sep.</td>
<td>9400</td>
<td>89625</td>
<td>273</td>
<td>20686</td>
<td>37018</td>
<td>196448</td>
</tr>
<tr>
<td>Oct.</td>
<td>9900</td>
<td>69750</td>
<td>192</td>
<td>36667</td>
<td>67785</td>
<td>171159</td>
</tr>
<tr>
<td>Nov.</td>
<td>9950</td>
<td>105417</td>
<td>621</td>
<td>61194</td>
<td>13646</td>
<td>176527</td>
</tr>
<tr>
<td>Dec.</td>
<td>10000</td>
<td>102083</td>
<td>600</td>
<td>5095</td>
<td>10885</td>
<td>168018</td>
</tr>
</tbody>
</table>

The water composition of the Lake Tuz also shows large seasonal variations (Table 1 and 2). In the summer period, when evaporation is most intense, the ionic concentration reaches values close to halite saturation before becoming oversaturated in this mineral. In the winter period, the concentration decreases to a minimum value due to rain (Table 1).

Table 2. Chemical composition (mg/l) of the Lake Tuz brine at June 1976 (Uygun and Şen, 1978).

<table>
<thead>
<tr>
<th></th>
<th>Deep zone</th>
<th>Main lake</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Çok yatan</td>
<td>Şehitler hani</td>
<td>Başhan</td>
<td>Selçuk</td>
<td>Kaldırım</td>
<td>Kayacık</td>
<td>Yavşan</td>
</tr>
<tr>
<td>Na⁺</td>
<td>28000</td>
<td>29000</td>
<td>112500</td>
<td>112500</td>
<td>110000</td>
<td>112500</td>
<td>110000</td>
</tr>
<tr>
<td>K⁺</td>
<td>420</td>
<td>430</td>
<td>1700</td>
<td>1200</td>
<td>1100</td>
<td>1200</td>
<td>1400</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>460</td>
<td>440</td>
<td>620</td>
<td>840</td>
<td>980</td>
<td>840</td>
<td>760</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>1.2</td>
<td>1.3</td>
<td>4.9</td>
<td>3.2</td>
<td>3.1</td>
<td>3.4</td>
<td>3.7</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>34</td>
<td>0</td>
<td>241</td>
<td>110</td>
<td>134</td>
<td>135</td>
<td>159</td>
</tr>
<tr>
<td>CO₃⁻</td>
<td>87</td>
<td>156</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>45000</td>
<td>47000</td>
<td>183000</td>
<td>180000</td>
<td>176000</td>
<td>180000</td>
<td>177000</td>
</tr>
<tr>
<td>SO₄⁻</td>
<td>3200</td>
<td>3500</td>
<td>10200</td>
<td>7700</td>
<td>7500</td>
<td>7900</td>
<td>8300</td>
</tr>
<tr>
<td>Sr²⁺</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>15</td>
<td>20</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>25</td>
<td>26</td>
<td>60</td>
<td>43</td>
<td>40</td>
<td>45</td>
<td>46</td>
</tr>
<tr>
<td>Br⁻</td>
<td>24</td>
<td>30</td>
<td>160</td>
<td>120</td>
<td>130</td>
<td>94</td>
<td>134</td>
</tr>
<tr>
<td>pH</td>
<td>8.5</td>
<td>8.9</td>
<td>7.3</td>
<td>7.2</td>
<td>7.3</td>
<td>7.3</td>
<td>7.3</td>
</tr>
</tbody>
</table>
The Na and Cl concentration of Lake Tuz stay almost constant along the year. But the concentration of other ions changes significantly during the year. There is a negative correlation between the Mg$^{2+}$ and Ca$^{2+}$ contents along the year: in early summer, the gypsum precipitation induces a marked decrease in the Ca$^{2+}$ content in the brine, which becomes enriched in Mg$^{2+}$. Such a high Mg/Ca ratio in the lake water has caused some dolomitization in the recent carbonate sediment of Lake Tuz (Tekin et al. 2007).

Pinkish to reddish brines, rich in halobacteria populations and other halophytic microorganisms are present from June to August along the shores of Lake Tuz and also along the edges of the salt pans (Tekin et al. 2007).

The water of Lake Tuz is significantly enriched in some elements, such as Br (3 ppm), B (5 ppm), Sr (3 ppm), and Li (12 ppm) (Tekin et al. 2007). The high lithium content (318–325 mg/l) in the brines of the Yavşan salt pans has an economical potential (Helvacı et al., 2004).

Evaporite formations deposited during the Maastrichtian, Paleocene, Lutetian, Upper Eocene, Oligocene, Upper Oligocene, and the Lower Miocene in the ancient Lake Tuz Basin are currently the main sources of solutes in the saline lake. These solutes are at present recycled by groundwater along some faults bounding the lake. For instance, several springs are observed in the main zone of the Tuz Gölü, near the Kaldırım salt pans (Uyanık, 2004; Tekin et al. 2007).

In the northern limb of the main zone, the mineralogy of the salt crust, which precipitates in summer, consists of halite, gypsum, aragonite, and calcite (Fig. 5). Below this salt crust, the mineralogy of the unconsolidated muddy sediments, whose thickness is almost 25 cm, is mainly composed of gypsum, huntite and magnesite. This unconsolidated level continues in the central part of the main zone, where polyhalite also occurs. In contrast, in the deeper zone, the sediments are composed of a thin layer of halite, gypsum, and aragonite. In the deepest parts of this zone and below the thin halite layer, the carbonate sediments are made up of Mg-calcite and dolomite (Tekin et al. 2007).

Figure 5. Salt crust in Lake Tuz.
In the field observation, cubic chevron type halite minerals in the upper levels of the salt crust was seemed to have dimensions of 0.5 mm-1 cm, and they were easily recognized and distinguished from the underlying halites by their clean colors in Lake Tuz (Kılıç and Kılıç, 2010).

Tekin et al. (2007) described halite oolites (halolites) and pisoids (halopisoids) precipitated yearly (in summer) in the brine conduits of the saltpans in Lake Tuz. These halolites are well rounded and spherical, ranging between 0.7 and 2 cm in size (Fig. 6). They are composed of coarse-grained halite crystals as the nucleus, and by concentric halite laminae with a radial fabric as the cortex.

![Figure 6. View and photomicrographs of haloolites from Kaldırım saltpans in Lake Tuz (Tekin et al. 2007).](image)

In Lake Tuz, there are over 279 plant species (8 sub-groups belonging to 3 separate plant alliance) and 120 halophytic bacteria recorded in the Lake Tuz ecosystem. Thirty-nine of these are endemic and, 4 of them are endangered. Additionally, there are 4 local endemic species which are not yet introduced to the scientific community. Moreover, there are important crop relatives or undomesticated plant species which can potentially be cultivated without much breeding efforts. There are 129 insect species of which 4 endemic, and 15 mammalian species (http://whc.unesco.org).
2nd STOP: LAKE BOLLUK

Lake Bolluk is a saline lake located about 15 km south of Cihanbeyli (Konya), to the west of Lake Tuz (Fig. 7). It covers an area of 11.50 km² (Fig. 8). There are sixty-three travertine cones of various sizes and diameters penetrating the gypsum-bearing clays of the Cihanbeyli formation at the northeast of the Bolluk Lake. Some of these cones are still actively forming. The travertine cones developed along the fault line and extend parallel to the trend of Lake Bolluk (Gündoğdu and Helvacı, 1996).

In flat areas between the Yapalı village and Bozdag where thermal and mineral waters are emerged, there are about 40 travertine cones extending north and northeast in an area of 12 km² around the Boluk Lake. The size of overturned plate-shaped cones differs from one to another. Their formation is consistent with general tectonic orientation. Cones with irregular shapes such as crater shaped, elongated and ring structured, have a spectacular view (Figure 9). Most of the travertine cones are semi-circular while a few are ellipsoidal. Basement diameter of the cones is between 11 and 200 m. Outlet diameter is 6 to 40 m and height is 1 to 11 m (Pasvanoğlu and Canik, 2007).

The high SO₄²⁻ content of the Bolluk Lake water was related to the sulfate-bearing waters issuing from these cones. Mirabilite (Na₂SO₄·10H₂O) crystallizes during the winter months in production pools in the Bolluk and Tersakan lakes. When the temperature reaches 25-30 °C in the months of July and August, the mirabilite crystals lose their water and are transformed into powdery thenardite (Na₂SO₄) (Gündoğdu and Helvacı, 1996).
Figure 8. Lake Bolluk, Lake Tersakan and Lake Tuz from west to east.

Figure 9. Travertine cones in and around Lake Bolluk.
Lake Beyşehir, which is the third largest lake in Turkey, is located between Beyşehir (Konya) and Fele (Isparta) Provinces. It occupies an area of 650 km² and is 45 km long and 20 km wide (Figure 10). The depth of lake is 10 metres at maximum and the altitude of the lake is 1123 m. The water in the lake is fresh and drinkable and is used for irrigation in the Konya Plain and for water supply of Beyşehir district.

The water level in the lake often fluctuates by year and by season. During the period 1960-1990, water in the lake had its lowest level in October 1975 at 1121.96 metres, with 645 km² of water surface and its highest water level in March 1981 at 1125.50 metres, with a surface area of 746.00 km² (http://en.wikipedia.org). The lake is fed by mountain streams and several springs derived from the Sultan and Anamas mountains and by precipitation.

There are thirty-three islets in varying sizes in the lake (Figure 11); Mada, Hacıakif, İğdeli, Orta, Kes, Aygır, Kızıl, Çeçen, Gölkaşı, Eşek, Kızıl, Kara, Tek, Akburun, İkinci Eşek, Taşlı, Geyik, Kirse, Kül, Keltaş, Yilan, Kız kulesi, kuş Kondu, Mondıras, Hüyük, Yapraklı, Sivri, Mındıra, Eylikler, Ardıçlı, Ladinli, Camız and Afrika islets. Mada islet is the largest one by covering an area of 8.22 km². These islets are considered as partially inundated hills. Three of the 33 islands are inhabited, others are farmed, the majority are deserted (Kazancı, 2003).

The water of Lake Beyşehir is alkaline, and within it are carp, trout, Pike, perch fish and Tench bass, turtles and snakes. Oğuzkurt, (2001) interpret the lake as dimictic having slightly thermal stratification due to physical aeration and orthograde and weak heterograde oxygen profile and as having ultra-oligotrophic level according water quality values and as being in beta-meso-saprobic level based on the content of phytoplankton, zooplankton and benthic macroinvertebrate species.

Fakıoğlu and Demir (2011) identified a total of 119 phytoplankton species from Bacillariophyta (42), Chlorophyta (48), Chrysophyta (1), Cryptophyta (4), Cyanobacteria (9), Pyrophyta (5) and Euglenophyta (10). Total phytoplankton biomass consisted of Bacillariophyta (53%), Chlorophyta (27%), Chrysophyta (3%), Cryptophyta (2%), Cyanobacteria (10%), Pyrophyta (4%) and Euglenophyta (2%). Mean values of chlorophyll a, total phosphorus and Secchi depth were measured as 8.24±2.08 mg/m³, 10.46±6.20 mg/m³ and 1.08±0.35 m, respectively. Dissolved oxygen was
measured between 6.36±0.06 and 11.63±0.06 mg/l. pH varied between 7.80±0.01 and 8.92±0.01. Water temperature changed between 5.3°C and 27.8°C. In the study period, phytoplankton biomass of Lake Beyşehir varied between 0.40±0.11 and 6.43±1.00 mg/L. The mean phytoplankton biomass (1.98±1.18 mg/L) of the lake pointed out mesotrophy and good ecological quality class.

Figure 11. Lake Beyşehir and the locations of historical/archaeological sites.

Lake Beyşehir is located in one of the most important karstic region in a structurally and tectonically very complex area in the middle and western Taurids (Fig. 12), which is called as the Isparta Angle comprising autochthonous and allochthonous rock units of various types and ages (Dumont & Keray, 1975; Boray et al., 1985; Poisson et al., 2003; Değirmenci and Gültekin, 1992, Koçyiğit, 1988, 1989, Karaman 2010). The autochthonous rock units consist mainly of calcareous and siliciclastic marine sediments that were deposited during the Mesozoic and Cenozoic. The allochthonous units form three main groups: (1) the Antalya nappes, which were emplaced in the region between the Cretaceous and Palaeocene, (2) the Beyşehir Hoyran nappes, emplaced in the Eocene, and (3) the Lycian nappes, emplaced in the Miocene.
The present structural features, especially significant faults and structural disruptions, were formed as a result of tectonic movement during and after Miocene time. Nappe forming processes that occurred at different geological times also have contributed to the structural complexity of the region. The direction of principal movements in the area up to Miocene time was North to South, where as the tectonic movements during and after Early Miocene which has caused intense folding in the region, were in a west-east direction. The east-west trending compressive forces on the southern part of the area were balanced by the northern tensile stresses (Dumont and Kerey, 1975; Boray et al., 1985; Poisson et al., 2003; Değirmenci and Gültekin, 1992, Koçyiğit, 1988, 1989, Karaman 2010).

There is a direct relationship between the general geology, tectonic structures and karstification. Most of the karstic feature, such as dolines, sinkholes, poljes, caves and springs are located along structural disturbances (faults, joints, etc). Naturally most of the karstic springs along these structural disturbance (Değirmenci and Gültekin, 1992).

Beyşehir, Eğirdir and Burdur lakes were developed in topographic depressions related to the host and graben originated as a result of abovementioned tectonic movements (Dumont & Kerey, 1975; Boray et al., 1985; Poisson et al., 2003; Değirmenci and Gültekin, 1992, Koçyiğit, 1983, 1984, Karaman 2010, Nemec and Kazancı 1998). They are closely related to each other and developed at the same time before Middle and Late Pliocene (Kazancı and Karaman, 1988; Nemec and Kazancı 1998, Karaman, 2010). Lake Beyşehir has developed in a graben between two dip-slip faults (Koçyiğit, 1984; Fig. 12).

![Geological map of the Lake Beyşehir and Konya region (MTA, 2002; for legend please see p.32).](image)

In addition to the natural beauty of the area, it also has an interesting history as it was governed by Hittites, Phrygians, Lydias, Persians and Byzantines. Finally, the Anatolian Seljuks conquered the area in 1076, and since then it has been under the reign of the Turks. The remains of Kubadabad Palace date back to the Seljuks, and are found on Kizkalesi Island, 3 km from the shore near Yenişarbademli town.
Some Archaeological and Historical sites around Lake Beyşehir

Erbaba

Erbaba is located on the eastern shores of Lake Beyşehir. The environment around the Erbaba differs from that of the Konya Plain in a number of respects. Annual precipitation is higher at ca. 500 millimetres, which makes rain-fed agriculture feasible. Mountains and woodlands are present at some 12 kilometres from the site. The environment of Erbaba was probably rich and varied in Prehistory as it is today.

Düring (2006) claimed that the site of Erbaba is of considerable culture historical importance for our understanding of the Neolithic of Central Anatolia for a number of reasons. For example, apart from Çatalhöyük, it is one of the few sites that can be dated to the Ceramic Neolithic of Central Anatolia that has been investigated. In this respect Erbaba complements the data from Çatalhöyük and puts that site in a regional perspective.

- First, relatively large exposures were excavated at Erbaba, which provide us with an insight into this Neolithic site at the settlement level.
- Second, the site differs in a number of important respects from the other Central Anatolian Neolithic sites, while in other respects clearly belonging to that cultural horizon. Most notably, the use of stone for construction purposes can be mentioned.
- Third, the landscape setting of Erbaba is very different from all of the other settlements that have been discussed. It is located on the fringe of Lake Beyşehir, and the marine component of the economy of Erbaba can be clearly documented.
- Fourth, Erbaba is a small site in a landscape with other contemporary small sites located at a close distance.

Eflatunpinar Monument and Pool

It is located about 22 km north of the town of Beyşehir. The monument is formed as a rectangular shaped pond fed with the waters from a nearby spring. The most prominent part is the high wall of reliefs that stand on the north edge of the roughly 34 by 30 meter rectangular pond (Fig. 13).

Figure 13. The Eflatunpinar monument.

Eflatunpinar is some of the few examples of frontal portrayal of human forms in Hittite art of the Empire period in Anatolia.
Kubadabad Palace

The Kubadabad Palace, established in 1235-1236 as the summer residence of Seljuk Sultan Alaeddin Keykubad (1220-1236), lies on the south-west shores of Lake Beysehir at the northern foothills of the Anamas Mountains, a branch of the Toros (Fig. 14). It was first discovered in 1949 by Zeki Oral, and consists of the Great Palace to the North (Fig. 15), the Little Palace to the south, and a shipyard beyond.

Figure 14. The Little Palace of Kubadabad Palace

Figure 15. Excavation of the Great Palace at Kubadabad Palace.
Eşrefoğlu Mosque

The Esrefoglu Cami is an outstanding example of the distinctive ‘wooden pillared mosques’ of the Seljuk Empire in the town of Beyşehir (Figure 16). It is a wooden mosque museum in terms of its superior wood and tile workmanship.

Esrefoğlu Mosque includes all the main elements of early Anatolian Turkish architecture. The building is the biggest, best preserved wooden columned and roofed mosque in Islamic World. (Wooden parts of the mosque was adorned by the richest examples of Kalemisi (hand-drawn) ornaments. This technique allows applying different colours on wood (http://whc.unesco.org).
Çatalhöyük

Çatalhöyük is a key Neolithic site located in south central Turkey (Fig. 17). It is one of the largest and best studied early agricultural settlements in southwest Asia (Fig. 18), and it has also revealed a significant record of symbolic expression, such as wall paintings. Çatalhöyük, in fact, comprises two mounds, an East mound where most excavations have been focused, and a smaller West mound of early Chalcolithic date. Çatalhöyük was originally excavated in the early 1960s by James Mellaart, but archaeological fieldwork subsequently stopped and recommenced only in 1993 under the overall direction of Ian Hodder—see Hodder (2006) for a summary.

Çatalhöyük is located on a gently sloping alluvial fan-delta of the Çarşamba River, which has prograded across the bed of a large former lake that covered the Konya basin during the late Pleistocene (Fig. 19). The plain lies at an elevation of ~1000 m asl and lacks any surface outlet. Its climate is semi-arid continental Mediterranean, in contrast to the surrounding well-watered mountain watershed. In contrast to initial speculations by Cohen (1970), studies by Roberts (1982) showed that (1) the main shrinkage of the Pleistocene Konya lake occurred prior to 16,000 BC, i.e., well before the first Neolithic occupation, and (2) significant post-occupation alluviation has occurred at Çatalhöyük. This continued deposition of alluvium means that modern soil type distributions (Driessen and de Meester, 1969) do not provide a reliable guide to those that existed around the site in prehistory. A comprehensive geoarchaeological field program took place between 1993 and 1999 linked to the current excavations at Çatalhöyük (Roberts et al., 1996, 2007). This KOPAL (Konya basin Palaeoenvironments) project included vibro-coring, back-hoe trenching, and study of off-site irrigation ditch sections, not only at Çatalhöyük but also at other archaeological sites located across the Çarşamba fan (Boyer et al., 2006).

Above pale grey marl deposited on the bed of the glacial-age lake, two principal alluvial units can be distinguished. A red-brown Upper Alluvial silt-clay dates from Bronze Age to post-Byzantine times. Beneath this lies a very dark grey Lower Alluvium comprising heavy, smectite-rich clay that was laid down in a seasonally flooded backswamp environment. The top of the underlying marl is
undulating due to Late-Glacial eolian deflation, and as a result, the backswamp clay infill shows local-scale variations in thickness. Deposition of the backswamp clay at Çatalhöyük began ~7500 BC and ended by ~6000 BC with paleosol formation, and it coincides in time almost exactly with the Neolithic occupation (Fig. 20). During the spring flood, much of the lower-lying land surrounding Neolithic Çatalhöyük would have been under water, which led Roberts and Rosen (2009) to propose that some cereal and pulse crops may have been grown on drier ground away from the alluvial fan.

Figure 18. A sketch illustrating the settlement of Çatalhöyük during Neolithic time.

In summer, the alluvial and marl plain dried out and the Çarşamba River returned to its main channel which ran next to Çatalhöyük. The strong wet-dry seasonal contrast in river and wetland hydrology has been confirmed by stable carbon and oxygen isotope analyses on samples taken across the surface of large Unio mollusk shells found on-site; the results for sequential samples showed isotopic variations explainable by seasonal fluctuations in local water levels as the bivalve’s shell grew (Bar-Yosef Mayer et al., 2012). The river “flooding phase” at Çatalhöyük appears to have prompted a nucleated rather than dispersed settlement pattern on the Çarşamba fan, for only this single large site is known during the ceramic Neolithic, whereas several smaller settlements existed during both the preceding aceramic Neolithic and subsequent early Chalcolithic periods. The distinctive lifeways at Neolithic Çatalhöyük may, in consequence, have been partly an adaptation to specific hydro-environmental conditions.

The “flood phase” at Çatalhöyük can be linked to a period of wetter climate in the eastern Mediterranean during the early Holocene, and its ending coincides with the well-known 8.2 ka BP cold, dry climatic event. However, lake isotope data show that wetter climatic conditions in central Turkey had started by 9500 BC and continued until ~4500 BC, thus spanning a longer time period than the Çarşamba flood phase. Its timing must therefore have been affected by local factors, such as river avulsion and a changing depocenter, as well as regional climatic changes. Its onset, for example, would have been affected by a change in river course from an easterly to a northerly orientation when the Çarşamba broke through a sand spit of the former Konya lake (Fig. 19).
Figure 19. Maps showing the changing distribution of sediments around Çatalhöyük, near the start and end of the occupation of the East mound; and at the present day (modified from Boyer et al., 2006). At the micro-scale, this pattern would have been more spatially heterogeneous than shown here.

<table>
<thead>
<tr>
<th>Age BC</th>
<th>Number of recorded settlement sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>8500</td>
<td>5</td>
</tr>
<tr>
<td>8000</td>
<td>6</td>
</tr>
<tr>
<td>7500</td>
<td>2</td>
</tr>
<tr>
<td>7000</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>Excavated sites</th>
<th>Flooding regime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic Neolithic</td>
<td>Pınarbaşı</td>
<td>perennial marshes, seasonal river flooding and alluviation, soil formation (= no flooding)</td>
</tr>
<tr>
<td>Ceramic Neolithic</td>
<td>Çatalhöyük</td>
<td>seasonal river flooding and alluviation, soil formation (= no flooding)</td>
</tr>
<tr>
<td>Ceramic Neolithic</td>
<td>Boncuklu</td>
<td>seasonal river flooding and alluviation, soil formation (= no flooding)</td>
</tr>
</tbody>
</table>

Figure 20. Chronological chart showing recorded archaeological site numbers on or near the Çarşamba fan, individual site occupations, and changing flood regimes (from Roberts and Rosen, 2009).
More recent geoarchaeological fieldwork has been extended to include the nearby predecessor aceramic Neolithic site of Boncuklu, as well as further analysis of the sediment fill at and around Çatalhöyük, e.g., the sourcing of mudbricks and lime plasters (Love, 2012; Doherty, 2013). A new program of coring and ditch sectioning around the mounds took place in 2007–2009 in order to build a picture of the site environs at higher spatial resolution. At this fine spatial scale, the Neolithic landscape would have been a mosaic of upstanding marl hummocks, seasonally-wet flood basins, and riparian-zone river channels, some of which would have provided micro-habitats suitable for more intensive “garden-scale” crop cultivation (Charles et al., 2014).

Çatalhöyük lies close to the volcanic terrain of Cappadocia, from where it obtained obsidian for lithic artifacts. A tephra layer found in eastern Mediterranean lake and marine cores has been linked geochemically to one of the Central Anatolian strato-volcanoes and dates to the ceramic Neolithic (Zanchetta et al., 2011; Schmidt et al., 2014). This may provide an explanation for an enigmatic wall painting at Çatalhöyük, which has been interpreted as showing a twin-peaked volcano erupting above a settlement.

The Konya Paleolake

The Konya Closed Basin is an important basin in Turkey in terms of its geographic position, quaternary aged infills and well preserved sites for searching the origins and development of agriculture and settled village life (de Meester, 1970; Roberts et al., 1979; Roberts, 1980, 1983; Erol, 1991; Kuzucuoğlu, 1993; Kuzucuoğlu et al., 1997; Fontugne et al 1999 and Boyer et al. 2006 many others).

The Konya Plain is a almost flat marl-filled former lake bottom having the altitude of which does not vary much around 1000 m, with lowest depressions at ca. 997 m. It covers an area of about 4200 km² and is located north of the Taurus ranges and south of the Tuz gölü (‘Salt Lake’) basin. It is separated from the Tuz gölü drainage area by a pass only 50m high, while the southern mountains rise up to over 3000 m. It is surrounded by the mountain Bozdağ (Bozdağ, a Paleozoic limestone palaeorelief with heights points of 1500 m) to the northwest and two stratovolcanoes higher than 2000 m; the Pliocene andesitic Karacadağ to the northeast and the Pleistocene differentiated Karadağ to the south (Fig. 21). The Konya Plain is cross-shaped, with its main basins located west (the proper Konya Plain) and east (the Ereğli Plain). Both parts are separated by a limestone bench joining the Karadağ and Karacadağ volcanoes. (Fig. 21). Two sub-basins were were separated from each other by volcanic cones and lava flows; the Sultanıye sabkha near Karapınar to the north and the Karaman depression to the South. The whole disposition of the plain is thus related to the Pleistocene karstic and volcanic evolution of the area (Fontugne et al 1999).

In the western part of the Konya Plain, three lower marshy depressions collect the water from the drainage basin and from the groundwater: the Yarma marshes to the north, the Konya marshes to the west and the Hotamış, lake to the south. These three marshy depressions are now (1990s) totally dry. Today, lake-like systems can only be found in eastern and northern parts of the Konya Plain: the permanent Akgöl lake adjacent to the Ereğli marshes; the Sultanıye lake, in the Karapınar depression, which is a seasonal lake transformed in summer into a temporary sabkha (Fontugne et al 1999).

The Konya plain is a closed karstic basin, fed by rivers coming mainly from the South (Taurus) and by underground water also fed in the south by melt waters and rainfall from the Taurus ranges. Part of the underground water flows northwards under the Obruk plateau, towards the Tuz gölü depression (Erol, 1991). Another part returns to the limestone basement through a few swallow holes, such as the Düden in the Ereğli plain or the Aşçıkuru in the West-Konya plain. During the Pleniglacial, these karstic losses allowed the Konya palaeolake water to remain fresh or lightly brackish (Fontugne et al 1999).

Eventhough the Konya basin comprises Quaternary lake marls and other, mainly finegrained, sediments (de Ridder, 1965, Robert 1983, Robert et all, 1999 ) with locally in excess of 400 m., the most obvious evidences of Late Quaternary environmental change were obtained from coarse-grained marginal shoreline facies and associated landforms (beach ridges, wave-cut cliffs, etc.) which surround the plain. Therefore most of the works done in relation to the climatic and environmental changes were conducted on these sediments. The past environmental changes recorded in these
sediiments have implications also for the human occupancy of South central Turkey, and in particular for the origins and development of agriculture and settled village life, as testified in Neolithic settlement sites such as Çatalhöyük (Mellaart, 1967; Hodder, 1997), Aşikli Hüyük (Esin, 1996) and Can Hasan III (French et al., 1972) dating from ca. 9000 $^{14}$C BP onwards (Roberts et al. 1999).

Kuzucuoğlu et al (1998) studied the dunes on the Konya plain (Fig. 22) and their relation to the climate. They interpreted three main stages of dune formation in the area, in relation with the drought periods during the Late Pleistocene and Holocene.

(i). the Ismil dune field: It is developed during last glacial drought periods (c. 45–35,000 BP) and last reworked in relation to the drought which followed the disappearance of the 17,000 BP lake,

(ii). the South-Karapinar dune field: It was mainly developed by drought which were effective from 17,000 BP to 13,000 BP.

(iii). The Akkum dune field at North-Karapinar. It is related to a Late Holocene drought (in the 6th to 5th millenium BP) which is also evident in the upper silts of some lacustrine sequences.

They related the dune systems of the northern shores of the Konya plain to the climatic changes during the Upper Pleistocene and the Holocene.

Karabiyıkoloğlu et al (1999) were identified eight principal sedimentary facies and six major lithostratigraphic units in these deposits representing progradational and retrogradational episodes of shoreline development in the sediment sequences developed at the northern margin of the Konya palaeolake near Göçü.

The lowest sequence is an aggradational unit formed by wind-driven currents and waves in a sand-dominant lake bottom above the wave base. It is overlain by a convoluted palaeosol $^{14}$C dated to ca 28,300 BP representing a major lowering of lake levels,

The next sequence is characterised by large-scale gravelly clinoforms that progressively offlap/downlap onto the underlying sequence, and correspond to progradation of a foreshore resulting from storm-originated oscillating and unidirectional currents, avalanching processes and minor subaqueous debris flows. It is overlain by an areally extensive lensoid body of structureless clays comprising a thin organic layer, abundant rootlets and freshwater mollusc shells, formed from suspension fallout in a quiet, very shallow freshwater lagoonal environment. This phase, representing a more minor lake regression, has been $^{14}$C dated to ca. 21,960-20,730 BP.

Figure 21. Map of the Konya basin sediments (Fontugne et al 1999).
The final sequences include large-scale sand waves and bars, which developed by storm-originated wave surges and strong shoreline currents, and prograding delta foresets. These sequences indicate a renewed lake transgression to higher water levels, before a final regression after 17,500 BP. Lack of tectonic deformation and the overall sedimentary characteristics of the beach system at Göçü clearly suggest that the sedimentary evolution of the system is closely related to lake-level fluctuations resulting from long- and short-term hydro-climatic changes. Successive stages of lake-level rises and large amounts of supply of coarse grained material imply a positive hydrological balance and relatively high rates of sediment discharge from the adjacent hillslopes.

![Figure 22. Main formations of the Konya Plain (Kuzucuoğlu et al. 1998) Legend: 1. Pre-Quaternary limestones and volcanics; 2. Limits of the Konya palaeolake; 3. Pleistocene, lacustrine marls; 4. Sand and gravel shore deposits; 5. Alluvial fans; 6. Dune systems; 7. Sebkha; 8. Marshes; 9. Lakes.](image)

Karabıykoğlu et al. (1999) concluded that the repeated alternation of progradational (highstand) and retrogradational (transgressive) systems of these shoreline deposits indicates deposition during an overall tendency towards lake-level rise, which may be related to long-term tectonic subsidence, along with interruptions by distinct lake-level drops of some magnitude. The maximum depth of the lake (ca. 20 m at this site) appears to have been reached during the phase corresponding to the deposition of Unit IV, ^14^C dated between 20,700 and 19,200 BP.

Roberts et al. (1999) interpreted two transgressive lake phase during Late Quaternary. (i) The first phase (Pleniglacial) began after 23,000 ^14^C yr BP and ended by 17,000 yr BP derived from abundant beds of the small bivalve mollusc Dreissena polymorpha (Pallas) collected within beach sands and gravels. The lake at that time occurred as a single and relatively shallow (30 m deep) but extensive (4000 km^2^) fresh or brackish water body (ii). The second phase which is much smaller was occurred during the Lateglacial period, and is generally associated with a malaco fauna dominated by gastropods such as Lymnaea spp. and planorbids, which are typical of shallower, more eutrophic and less turbid water. This lake phase was restricted to isolated secondary depressions within the main basin. They think that, in contrast to most deepwater non-outlet lake systems, the Konya basin may
have been occupied by a single extensive lake for as little as 10% of Late Quaternary time, mainly around the time of the LGM. This lake highstand was followed by an important arid interval.

Fontugne et al (1999) studied Konya plain sediment by dividing them into four phases

1. **Upper Pleistocene (pre-Pleniglacial) sediments**: These sediments comprise organic matter-rich paleosols interstratified with lacustrine deposits. Organic matter from this paleosol has been dated 28,300±1100 yr BP from Göçü quarry and 24,400±800 (Gif/LSM 9749) from organic matter and mollusca-rich layer from Ereğli VAH well.

2. **Pleniglacial sediments**: They are represented by sediments of five periods marked by lake expansion and disappearance;

   (a) **Period 1**: from prior to >22.1 to 20.6 kyr BP, the lake reached a high level (20 m depth), covering the entire plain and inundating the limestone bench in the middle of the Konya Plain (Figure 23),

   (b) **Period 2**: from 20.6 to 19.5 kyr BP a lake contraction may have occurred, leaving a general unconformity in the stratigraphy of the coastal sequences,

   (c) **Period 3**: from 19.6 to 19.0 kyr BP, the lake level rose again reaching again ca. 20 to 30 m high lake level stand, as testified by the best preserved beaches,

   (d) **Period 4**: from 19.0 to 18.5 kyr, there is no material dated between this period which may correspond to a drop in lake level, also indicated by the development of palaeosols dated ca. 19 kyr BP.

   (e) **Period 5**: from 18.5 to ca. 17.0 kyr BP, the third lake phase is marked by the highest lake level stand (20-30 m depth), as testified by the best preserved beaches and numerous dates; Around 17,000 yr BP, the lake disappeared completely and probably abruptly. This ‘dry’ period, which has left no other sign than a total absence of deposits or some possible material reworked in the subsequent lake or dune systems, lasted from 17.0 to 15.4 yr BP.

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**Figure 23.** Upper Pleistocene Lake systems of the Konya Plain (Fontugne et al 1999).
3. Lateglacial lacustrine and marshy (mollusca-rich) deposits and dunes: Deposits belonging to this period are lacustrine (marls, sometimes associated with shallow-water mollusca other than Dreissena) or marshy (mollusca-rich black organic layers) and show that repeated phases of lake contraction-expansion occurred during the Lateglacial; lake level rises always concentrated in sub-basins and no longer covering the whole plain. Lateglacial shallow lake rises two times during this period separated by a drought.

a. The first Brackish shallow lake period (ca. 15,600 yr BP)
b. The mid-Lateglacial drought (ca. 14,000-13,500 yr BP)
c. Second Lateglacial lake period (ca. 13,500-11,000 yr BP)
d. The Younger Dryas (starting at 11,000 yr BP, ending ca. 10,000 yr BP)

4. The Holocene sediment.

a. The Early Holocene (10,000 yr BP-5600 yr BP) At ca. 8500 yr BP, palaeosols (Phase G1) developed. Between 9000 and 8000 yr BP there was a marshy backswamp environment immediately north of Çatalhöyük (Roberts et al., 1997). During the thousand years from ca. 8000 to 7000 yr BP, there is no lake nor marsh deposit known. Marshes and very shallow lakes reappeared shortly during the following period (6000-5700 yr BP).

b. The Mid-Holocene drought (ca. 5600 yr BP)" Phase H. The second dune system in the Konya Plain consists of 16,000 to 20,000 ha of wind blown parabolic sand dunes accumulated northwards against the foot of the basaltic lava flow close to Karapınar town.

c. Late Holocene" None of the deposits dated to the Late Holocene (4700 yr BP) belongs to lake-related conditions. Some marshes appear in a few sub-basins, but with no accompanying molluscan fauna. Instead of lake renewal or wetland expansion, there seem to be signs of alternating slope erosion and slope stabilization periods, as shown by the formation of palaeosols within the colluvium covering the Pleniglacial beaches at Külbasan.
5th STOP: MEKE MAAR LAKE

Figure 24. Trip route for Meke Maar Lake visit.

Meke Maar Lake named after a bird (coot, "sakarmeke" in Turkish) is one of the rare geological structures in the world. It is a maar lake located 8 km southeast of Karapinar (Konya) town and two km south of the Karapınar-Eregli highway (Figure 24) in the basaltic Karapınar volcanic field comprising five cinder cones, two lava fields and several explosion craters and maars. It is one of the largest cinder cones in Central Anatolia.

The Meke Maar has an ellipsoidal shape with 1800 m of length and 1600 m of width and about 100 m of depth. The lake in the middle of this maar has a length of 1100 m and width of 800 m (Figure 25). In the middle of this lake, there are a main and three parasit cones made up of basaltic and rhyolitic pyroclastic materials as islands. The main cone has a height of 120 meter from the base of the lake. There is a 25 deep crater (called as the "eye" of the lake) on the main cone.

Present day morphological characteristics of the Meke maar took place after two phases of volcanic activity. The primary maar was developed after a volcanic eruption about 4 million years ago (Ayhan and Baş, 1984). The Meke lake partly fills about 100m deep crater. The water is mainly derived from rain, snowfall and underground. The cinder cone in the middle of the lake was formed by an eruption taken place about 9000 years ago. The special volcanic mess that forms the the cinder cone has an ability to absorb even the most heavy rain showers. That is the reason why Meke has preserved its shape for thousand years.

The geological characteristics of the Karapınar area around Meke Maar is given on Figure 26. The rocks around the lake and on the cones in lake comprises pyroclastics materials such as lapilli, ash, volcanic bombs and rock fragments in basaltic and andesitic composition (Fig. 27).

Surge deposits with characteristic features such as thinly to thickly laminated planar and slightly wavy bedded structures, lenses of well-sorted and well-rounded pumice lapilli and wavy-, lenticular- or low angle cross bedding are common on the walls of the maar.
Figure 25. An aerial photo of Meke Maar Lake (Arık et al 2010).

Figure 26. Geological map of the Konya-Karapınar basins (MTA, 2002; for legend please see p.32).
The lake is in saline character with high concentration of K, Mg, Na, Ca, SO4 and Cl ions. The lake was a site of salt production for a long time in history. Recently due to drop in ground water level, salt layers were deposited at the base of the lake (Figure 28).
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Figure 29. Digital elevation model of the Ankara-Konya region.
Figure 30. General geological map for field excursion of QuickLakeH2014 (MTA, 2002; for legend please see p.32).
Figure 31. Legend for the geological maps of MTA (2002) at pages 4, 12, 25, 31.
Figure 32. Road map for Ankara-Konya region.